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"The photostat document hereunder covering the German 80 M. M. Photophone Equipment has been downgraded to CONFIDENTIAL Security Information."

James G. Hiemenz

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M626. SECRET. 01-52754 PART II

THE 80 MM. GERMAN PHOTOPHONE

BY

M. BOUND.

W. ROGULSKI.

SERIAL NO. 30

ADMIRALTY SIGNAL EST.

JULY 1944.

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ADMIRALTY SIGNAL ESTABLISHMENT,
Lythe Hill House,
Haslemere,
Surrey.

SUMMARY OF REPORT.

1. This report describes the current model of the German 80 mm. Photophones and also gives a short history of the development of the instrument as recorded in the Patents taken out by Zeiss who manufacture the instruments.

The following is a condensed version of the relevant data on the instrument.

2. Transmitter. This is a lens transmitter using a doublet lens of 80 mm. diameter and a 4 watt (4.8 volt) tungsten filament lamp. Siemens laboratory report No. 25/1943 gives the photometric measurements made on the lamp.

2.1. Peak visual candle power of beam is 10,000 c.p.

2.2. Spread of beam is 7 yds. per mile.

2.3. The modulation of the light beam is novel and depends upon the fact that under conditions of total reflection the intensity of the reflected light can be changed by bringing a second surface situated in the less dense medium near the reflecting surface. Modulation at audio frequencies is effect electromagnetically either from a microphone with one stage of amplification or from a telephone line with two stages of amplification.

2.4. Filters. The transmitter may be used without any filter or with one of two filters; one of these filters is a red filter used in daylight whilst the other is an infra-red filter used at night.

2.5. Training. On account of the small spread of the beam accurate training of the projector is essential. This is accomplished by means of a sighting telescope fitted with a 'tripelstreifen' which is a modified corner cube reflector.

3. Receiver. The receiver lens is mounted parallel to the transmitter in the head and is automatically trained on the distant station when the transmitter is trained on that station. The receiver lens is a crossed lens of 80 mm. diameter.

3.2. Photocell. The photocell employed is a very small sensitive area thallium sulphide cell of the non vacuum type. This cell has a very low 'lux' sensitivity (see A.R.L. report ARL/N1/E.320 where the lux sensitivity is reported) but a very good 'lumen' sensitivity. (See A.S.E. report M.518 where the 'lumen' sensitivity and frequency response are quoted).

3.3. Receiver Amplifier. This is a three stage amplifier with the first stage in the receiver-transmitter head. The output may be fed into headphones or a telephone line.

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4. Ranges for speech.

The ranges quoted in the German handbook are:-

(a) for white light 3 kilometres.

(b) for red filters 3 kilometres.

(c) for I.R. filters 2 kilometres.

5. Visual Morse Signalling. The apparatus has also been designed to be used for visual signalling, for which purpose an auxiliary lens is used to give about double the normal spread.

5.1. Ranges for visual signalling. The ranges quoted in the German handbook are 2 km. in daylight and 4 - 6 km. at night.

6. Weights. (taken from M.E.F. Report No. 85).

Amplifier box including H.T. batteries	15½ lbs.
Battery box minus battery.	9¼ lbs.
Tripod.	6½ lbs.
Head packed in case.	12½ lbs.
Batteris (estimated).	10 lbs.
	53¾ lbs.

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HISTORICAL INTRODUCTION.

The first record of the system of modulating a light beam, used in the present German photophones set, is a patent entered by Carl Zeiss of Jena in the German Patents Office in 1928. The development of the system may be traced in a series of British Patents taken out by Zeiss from 1929 onwards.

British Patent 317,318, dated 1929 corresponding to the above German Patent, describes some of the original attempts at producing a modulator using two grids which move relative to each other; this method has the attendant disadvantage that half of the possible flux from the transmitter is lost.

This patent describes the basic idea of the modulator used in the present photophone. It states that "To avoid the loss of light due to the use of modulated grids a pencil of light is incident on a glass air boundary under the critical angle of reflection and a second glass plate is caused to move so that it touches the fixed glass surface nearly or completely thus varying the intensity of both the reflected and transmitted pencils. Experiments have proved that the alterations of intensity take place not only during the movements of the complete separation of the glass surfaces but that such alterations take place also when the moving glass has a distance of one light wavelength from the fixed glass surface." The original patent also covers the applications of the method to determine translations of the order of half a micron, or small rotations.

British Patent No. 442,228 in 1934 describes the instrument almost as it appears to be constructed and used in this war. Patent No. 450,946 describes methods of increasing the dispersion for use in visual signalling and these modifications are included in the models examined and reported on herein. This patent also describes the use of a 'tripel-streifen' (which will be described later) for training the apparatus on to a distant station. Thus the Germans have made no secret of this apparatus and in fact allowed the Polish Government to buy two before the war.

Various reports from Allied sources give certain details of this outfit. These include:-

(1) Report by Signals Experimental Group MEF Report No. 85.

(2) Report by 849th Signal Intelligence Service Signal Section (dated 15/2/43).

(3) Article in Electronic Engineering (September 1943).

A.S.E. has been allowed to examine a model of the German photophone by courtesy of S.R.D.E. (M. of S.). The following report records the tests carried out on this apparatus and is intended to amplify previous reports. In order to make the report as complete as possible, certain measurements recorded in the above reports have been repeated and recorded.

I. GENERAL DESCRIPTION OF THE INSTRUMENT.

The modulator works on the well known principle that even under conditions of total reflection radiation penetrates the second medium to a depth of a few wavelengths. (Woods Physical Optics Third Edition page 418). Furthermore the amount of the light

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r ected at the interface under conditions of total reflection can be in.luenced by bringing a second surface into the radiation which has penetrated through the interface. It was found experimentally by Zeiss, as stated in the Introduction, that the intensity of the reflected beam varies continuously with the separation of the two surfaces when the separation is small.

In this instrument the two media are made of glass and the oscillation of one glass relative to the other at speech frequencies is accomplished by mounting the glass plate on a soft iron bar in a magnetic circuit the flux through which is varied by means of speech coils.

The modulated light signal is received upon a thallium sulphide photo-conductive cell and amplified in the usual way with a thermionic amplifier.

The apparatus, employing the above principle, consists of a transmitter-receiver head mounted on a tripod (Fig. 6) and two boxes which can be clamped together, as shown in Fig. 15, containing the amplifiers and batteries. The transmitter and receiver optical trains along with the transmitter modulator, the receiver photocell, and the first stage of the receiver amplifier are housed in the head. The a lifier box contains the two stage modulator amplifier which may be ed either from a microphone or a telephone line, and two stages of t receiver amplifier. Fig. 15 shows a general view of the amplifier s and the positions of the various articles such as headphones, microphones, switches etc.

II. OPTICAL CHARACTERISTICS OF TRANSMITTER.

1. Description of the Modulator.

Figs. 1, 2 and 3 are photographs of the modulator whilst Fig. 4 is a schematic layout of this apparatus. It will be seen from Fig. 4 that reflection at angles of incidence greater than the critical angle takes place on one side of a rectangular prism (a. Fig. 3 and 4). The moving glass plate forms the lower surface of the prism q of Fig. 1 and this prism which also serves another purpose as will be indicated below (para. 7) is carried in an iron plate b Figs. 1, 2 and 5. This iron plate b, is capable of oscillating about a line through the knife edges CC which are pressed against the face of the main prism by the spring loaded screws (d Fig. 2). The plate is made to oscillate by the varying flux through speech coils (f Fig. 2). The four sets of pole pieces (e Fig. 2) two parallel elements of the magnetic circuit, the rest of the circuit consisting of the permanent magnet (L Fig. 2) and the iron plate (b Figs. 1 and 2), and the windings of the speech coil are such that at any instant one pair of coils increases the flux through one of the two parallel elements and thus attracts one end of the plate b whilst the other pair of speech coils decreases the flux through the second of the two parallel elements and thus lessens the pull on the other end of plate b. In this way a couple is applied to the plate b. The ement of this modulator plate (b) need only be small for effective ulation of the light beam. The oscillation of the plate b takes ce against the spring h (Fig. 2) whilst the quiescent separation of the modulator plate and the main reflecting prism is controlled by the I (Fig. 1) operated from the modulator control J (Fig. 6) through nked arm and universal joint. This control varies the position at which the roller K (Fig. 1) presses against the modulator plate on the

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small prism side of the axis of rotation CC of the plate.

The modulator glass disc is provided with a system of crossed narrow flutes which the patent claims prevents an undesired adhesion of the moving body to the reflecting prism.

2. Optical train of the Transmitter.

The optical train of the transmitter is shown diagramatically in Fig. 4. An image of the filament of a tungsten lamp is focussed on or near the flutes of the modulator by means of a doublet condenser lens (p Fig. 4) and the usual spherical backing mirror (m Fig. 4) which gives a second image of the filament on the flutes. These images are formed at the focus of the 80 mm. diameter doublet transmitting lens the resulting beam having only a width of 7 yds. per mile. It must be realised, therefore, that the training of the projector must be done accurately and for this purpose Zeiss have made use of the 'tripel-streifen' which is described below.

Measurements of the candlepower of the beam without any filters and with the best setting of the modulator for speech reproduction showed it to be 10,000 c.p.

3. Tripelstreifen.

This is a special form of the corner cube reflex reflector and is shown in Fig. 7. It will be seen that it consists of a rectangular glass bar with two reflecting surfaces at one end, and one at the other end, so placed that all three surfaces are mutually at right angles (the corner cube reflector principle). The face N (Fig. 7) of the rectangular glass bar has been ground to prevent reflection taking place from it, whilst all the outside surfaces, except those required to transmit light, are painted black. The reflecting glass surfaces are silver plated (a common practice with reflex reflectors); this prevents possible loss of light due to greasy reflecting faces.

The position of the tripelstreifen is shown at u in Fig. 8 where it is mounted so that part of it covers the sighting telescope v and part of it covers the transmitting lens. When mounted, approximately one half of the prism fits into a rotatable casing carrying two red filter over the lower end of the prism which faces the transmitting lens. The use of these filter will be described below. Change from one filter to another is readily made by rotating the casing.

The tripelstreifen works on the principle that each ray of a bundle of rays incident on the two reflectors at one end emerge from the other end exactly parallel to their original direction but both displaced and reversed in direction. Thus the bundle of rays emerging from the transmitter in front of the tripelstreifen which would form an image of the filament at infinity is diverted into the telescope, and when the latter is focussed for infinity an image of the filament spiral is formed on the field of view of the telescope.

This image of the filament must fall on that part of the image plane of the telescope corresponding to the position of the real image of the filament formed by the transmitting lens (except for the negligible displacement introduced by the tripelstreifen) and the process of training the transmitter is reduced to that of superposing the red image of the filament as seen in the telescope upon the image of the required distant station also seen in the telescope.

Since the image of the naked filament would be too bright to be viewed directly in the telescope, the end of the tripelstreifen facing the transmitter lens is fitted with two interchangeable red filters, the lighter of the two being for use in daytime since it is then more difficult to see the image of the filament against the bright field of the telescope.

It must be observed that the tripelstreifen makes use of the non paraxial rays from the transmitter and hence for accuracy this lens must be free from aberrations. It has already been pointed out that the transmitting lens is a doublet and is therefore fairly well corrected for aberrations.

When the instrument is used in the infra-red a device is introduced so that the image of the filament can be seen in the sighting telescope; this device is explained in II.5b.

4. Lamp.

Fig. 14 shows two shadowgraphs of the filament of the lamp. Messrs. Siemens have photometered the lamp for A.S.E. and issued a full report on it (Laboratory Report No. 25/1943). It is a 4 watt 4.8 V. lamp and at the correct voltage has a mean horizontal candle-power of 3.6 and an efficiency of 9.77 lumens per watt. It is interesting to point out that Messrs. Siemens reported the quality of the glass bulb as being better than normal commercial quality.

The lamp is capped with a prefocus cap and is very readily exchanged when defective by removing its holder Z (Fig. 6) from the bottom of the head.

As the lamp is also used for Morse signalling by keying the current through it the transient characteristics of the lamp were measured. The incandescence time (i.e. the time taken for the light to attain 90% of its steady value from the time of switching on the current at 4.8 V.) is 0.140 seconds whilst the nigrescence time (i.e. time taken by light to fall to 10% of its steady value on switching off current) is 0.026 seconds.

5. Filters.

The filters are carried upon a wheel W (Fig. 9) with four locking positions and it can be adjusted to lock in any of the four positions from the back of the transmitter head by means of the control (Fig. 6). There are four circular apertures in this wheel one of which is empty, two of which carry red and infra-red filters respectively, and the fourth of which carries a plano-convex lens the use of which will be described below in II.6. The empty aperture mentioned above is used when it is desired to signal or telephone with white light. The two filters consist probably of dyed gelatine mounted between glass discs; these are described below.

a. The red filters.

As well as the red filter carried on the wheel W each outfit is supplied with a light red filter to cover the telescope eyepiece. The purpose of this is probably to increase the contrast of the red image of the filament (used in the training of the projector as described in II.3) against the light telescope backgrounds obtaining in daytime. The spectral transmission of this filter is shown in Fig. 10.

The other red filter, used to screen the transmitter was unfortunately too badly crinkled for measurement. It is not however believed that this filter is identical with either Wratten 89 or 89A which were originally designed for semi secret visual signalling during daytime (see Wratten light filters 12th Edition p. 88). During daytime the use of this filter would make the transmitter difficult to detect visually.

b. Infra-red filter.

The spectral transmission of this filter is shown in Fig. 10. The bulk transmission of the filter (using an I.R. sensitive C.M.G. 8 photocell) is 60% of that of a Wratten 87 filter, and the filter resembles a British 4% N.L.C. fairly closely in spectral transmission.

When using this filter the image of the filament of the transmitter lamp will not be visible in the sighting telescope and hence the usual method of training the projector fails. To overcome this difficulty a small red spot is introduced near the periphery of the infra-red filter; this spot transmits red light and is so placed that the radiation passing through it also passes through the aperture X (Fig. 9) and falls on the tripelstreifen. To allow some tolerance in the positioning of the red spot in the infra-red filter, it is made larger than that required only to fill the aperture at X with red light. This aperture in turn can be adjusted by hand (it is not fixed) so that the radiation passing through it falls exactly on the tripelstreifen. The red light which does not pass through the aperture at X is cut off by a green filter (R Fig. 9) (which however allows the infra-red to pass) and thus no visible red light is projected by the lens since all the red light which passes through the aperture X falls exactly into the tripelstreifen and hence into the sighting telescope.

6. Gestraut Position.

As stated above, wheel W of Fig. 9 also carries a small plano convex lens of 20 cms. focal length with the plane side towards the lamp. This lens has a small rectangular aperture cut in it which serves the same purpose as the red spot in the infra-red filter described in II.5b. This lens is used to increase the dispersion of the beam for white light visual signalling. When used in this "gestraut" position the dispersion of the beam is about doubled.

7. Modulation Monitor.

As stated in II.1 the prism q (Fig. 1) which carries the modulator glass plate has another function. By means of a train of prisms and a green filter an image of the surface of the modulator with its grid of narrow flutes is superposed upon the edge of the field of the sighting telescope. Thus on looking into the telescope a red image of the filament is seen in the centre of the field and at the bottom of the field of view, if the modulator control is near the correct setting, two green overlapping images of the filament are seen (the second being due to the spherial backing mirror which gives a real image of the filament alongside the actual filament) with a faint green background crossed by a grille of dark lines due to the flutes on the modulator plate. This monitor system can only be used to obtain an approximate position of the modulator control but it indicates whether the modulator is or is not working. If, when the apparatus is properly set up, the microphone is shaken the green image of the filament flickers. This is really a test for overloading and when speaking into the microphone normally no flicker of the image is observed.

III. OPTICAL CHARACTERISTICS OF RECEIVER.

The receiver lens is a 80 mm. diameter single crossed lens giving the minimum spherical aberration obtainable with a single lens. The focal length is 20.5 cms. measured from the back surface of the lens. The thallium sulphide photo-conductive cell shown in Figs. 12 and 13 is located in position y (Fig. 6) at the focus of the lens by means of the press studs shown in Fig. 13, which make it easy to change a cell when required.

The sensitive area of the cell is very small about 1 mm. in diameter and is covered with a red filter. Because the sensitivity of the cell to modulated light decreases with increase of unmodulated light falling upon it the field of view of the receiver must be reduced to the minimum practical size when the apparatus is used in daylight. This may be accomplished in two ways; (a) by using a photocell of small sensitive area slightly larger than the circle of confusion for the receiver lens, or (b) by using a cell of larger area mounted behind a small aperture at the focus of the receiving lens. The first method has another advantage without whose use the apparatus could not have been designed (unless the Germans have the equivalent of the British S/T cell). The 'lux sensitivity' i.e. the sensitivity in a uniform field of 1 lux, of the German point source is very much smaller than that of the standard 1" square British cell. For photo-conductive cells the lux sensitivity is independent of the area of the cell and hence the lumen sensitivity i.e. the sensitivity to one lumen can be made very large by making the area of the cell small. For low intensities (where the cell is linear) the lumen sensitivity is independent of the area of the cell upon which the radiation falls. When used with an optical system the lumen sensitivity of the cell is the essential characteristic. Taking the above factors into consideration the German point cell used with method (a) can have a lux sensitivity of only 1/800th that of an S/T cell and yet give the same overall sensitivity as that given by the S/T cell. In fact through the usual audio frequency band (300-3000 cycles) the German point cell has better lumen sensitivity than the S/T cell (see A.S.E. Report No. M518).

The red filter which covers the sensitive area of the cell has the effect of decreasing the desensitising effect of the unmodulated daylight background by removing most of the white light without materially decreasing the infra-red signal received from the distant transmitter.

The very small field of view of the receiver necessitates that the transmitter and receiver lenses in the photophone head be accurately aligned so that when the transmitter is trained on the distant station the receiver is also automatically trained on that station for receiving the replies. This aligning is of course done in the factory.

IV. THE ELECTRICAL CHARACTERISTICS OF THE TRANSMITTER.

General. The electrical circuit of the transmitter amplifier is shown on the right of Fig. 16. The various items are described under the appropriate headings below.

1. Valves.

Both the receiving and transmitting amplifiers use only one type of valve (a pentode), a practice which simplifies the supply of spares.

2. Operation with microphone.

When the transmitter is used with a microphone, only one stage of amplification is used. The microphone output is fed into the grid of this valve through a microphone transformer in the usual way. The output from this single stage to the modulator speech coils is made through a choke-capacity coupling, the four coils being coupled in series and shunted with a condenser as shown in the circuit diagram Fig. 16.

3. Operation from telephone lines.

When the transmitter is operated from balanced telephone lines another stage of amplification is necessary. In this case also the output from the lines are transformer coupled to the grid of the first valve of the two stage transmitter amplifier. The two stages of the amplifier are coupled through the microphone transformer using an auxiliary winding on the primary of the transformer.

4. Overall frequency response of the transmitter.

The overall frequency response of the transmitter was determined, for the best setting of the modulator control for speech reproduction, by feeding a known voltage from an audio-frequency oscillator into the microphone sockets. The modulated light output was measured with a photocell and amplifier with a flat frequency response and the results obtained for various input volts are shown in Fig. 17.

It will be observed from these curves that the modulated light output falls rapidly below 300 c.p.s. and above 2200 c.p.s. and that for low volt inputs the frequency response is somewhat peaky but this will be of little importance in practice as the output from the microphone may be 1/10th of a volt or more.

5. Depth of Modulation.

An estimate of the depth of modulation of the transmitted beam was made both with a rotating mirror and by using the same set up as that described in 4 above. The results with the mirror showed that the beam was deeply modulated with inputs of the order of one volt. With the second method the output from the photocell amplfier was measured for various input volts to the microphone sockets at four frequencies taking care that the output from the photocell amplifier was sufficiently small not to produce distortion. Also the output from the amplifier was determined with no modulating voltage applied to the microphone sockets, but with the transmitter beam chopped mechanically. Unfortunately it was not possible to produce a sinusoidal wave with the mechanical chopper and thus it is not possible to measure the percentage modulation but some indication of the percentage modulation can be obtained from the results. The value of the output for the mechanically chopped quiescent beam is shown by the dotted abscissa (output - 200 μW) in Fig. 18.

The curves were taken at larger input volts than were those for the frequency response in Fig. 17. The light output is approximately proportional to the input volts up to 2 volts and at this voltage the % modulation varies from about 60% at 400 c.p.s. to 100% at 1000 c.p.s. The above warning must be remembered with respect to these percentages.

V. ELECTRICAL CHARACTERISTICS OF RECEIVER.

1. - Amplifier.

The circuit diagram of the receiver amplifier is shown on the left of Fig. 16. The first stage of the amplifier is situated in the head, a practice which is common with photocell amplifiers to reduce distortions which would otherwise be introduced by the necessary length of leads to the main amplifier.

The amplifier is a three stage resistance capacity coupled amplifier characterised by a small value of the time constant of the coupling network which cuts off the frequency response at the lower end of the audio-frequency scale. There are two reasons for doing this as explained in A.S.E. Report No. M517 on Portable Telephony sets using S/T cells. The first reason is that thallium sulphide cells have a frequency response which is a monotonically decreasing function of frequency; thus the cell emphasises the low frequencies and this is counteracted by having the frequency response of the amplifier cancel out this effect. The second reason is that disturbing effects due to heat haze or similarly slow fluctuating background light is reduced to a minimum. The headphones form the anode load of the last stage with a rather [illegible]l volume control consisting merely of a resistance shunt across the headphones. The output from the receiver may also be fed into a telephone line for relaying to a more distant station.

2. Cell.

As stated above the photocell is a thallium sulphide photo-conductive cell. The cell and its 10 MΩ-matching resistance is supplied with 30 volts from a potentiometer across the 60 V. battery supply. A.S.E. had previously made measurements on the frequency response of this cell up to 400 c.p.s. but had no gear available for making measurements at higher frequencies. The frequency response curve for the cell quoted by the Army is fairly flat up to 1500 c.p.s. and falls by 4 db at 3000 c.p.s.

3. Quality of the speech reproduction.

It will be seen from the frequency response curves of Fig. 17 that the effective audio-frequency band extends from about 300 c.p.s. to 2200 c.p.s. From the curves published by the Bell Laboratories of America (quoted in Reference Data for Radio Engineers S.T. and C. Ltd.) 80% of the syllables should be understandable and since extending the response range up to 3500 c.p.s. only increases the above percentage to 85% it is seen that the rather limited frequency band of the receiver has only a small deleterious effect upon the speech reproduction.

VI. OPERATION.

[illegible] Dominant factors for any application.

The application of this instrument is governed by the following factors:-

(a) Although the apparatus is readily transportable it can only be used between fixed stations which are visible to one another.

(b) A pair of transmitter-receivers can be used as a link in a telephone line since one photophone can be operated into or from a telephone line.

(c) The range obtainable depends on the weather conditions and the apparatus would be useless in either a fog or chemical smoke.

The apparatus may be used to establish communication across rivers or similar obstacles but primarily it is believed that it was designed for front line operation to replace the normal field telephone set where the lines are constantly under shell fire. One transmitter some way back from the front line may be used as an exchange, feeding into telephone lines, for a number of front line stations each in turn calling up the exchange by using visible light in the gestraut position who then trains his apparatus on the calling station. Other applications can be envisaged for this apparatus and many are described in the German Photophone handbook.

2. Setting up the Photophones.

When it is permissible to use white light the problem of training the photophone is relatively simple during day or at night. If the use of white light is not permissible the photophones may still be trained accurately during daytime using the infra-red filter, if the positions of the distant stations are known by some landmark. The German handbook recommends that the station working forward towards the enemy lines should not use white light but this of course is not always possible.

The method of training the photophones having been described above it remains only to describe the method of obtaining the best modulator setting.

The following instructions were obtained partly from the German handbook and partly from experience with the instrument.

The quality of the speech depends almost entirely on the modulator control setting. In making the best setting the green grille in the bottom of the field of the sighting telescope is observed and the modulator control turned continuously from its zero position until an image of the filament appears upon the grille. This position is usually found to be satisfactory for operation and on whistling into the microphone the brightness of the filament will flicker. If however this setting is not entirely satisfactory the following procedure should be followed.

By previous arrangement between the stations one station reads out to the other station, the number of the graduation of the modulator control after each adjustment and receives the comment of the second station on the intelligibility of the speech and directions for the setting for best reproduction. If necessary the second station can adjust in the same way. It will be realised that this method can be tedious if both stations need adjusting because the examining station comments may be unintelligible to the sender station.

VII DESIGN.

The construction of the apparatus exhibits characteristic German 'sitzfleisch'. Every detail has been well thought out, and

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well designed but a general criticism of it is that it is too complicated for military use.

Mechanical design.

The design of the apparatus for portability has been well thought out and so has the mechanism for training the photophone head, e.g. the independent clamps for each leg of the tripod. The use of a single die casting for the amplifier chassis is in keeping with the usual German practice.

Valves may be changed readily by removing a panel held in position by one screw only. The lamp in the same way is very readily changed without upsetting the training of the head.

Instructions for using the apparatus are printed on the top of the photophone head and hence cannot get lost. Very many of the controls are labelled and by an ingenious use of a prism the modulator control is faintly illuminated for night operation. Everything possible has been done to make the operation of this instrument as easy as possible.

Electrical Design.

The layout of the components is very neat and compact each component being numbered and all connections colour coded. This aids rapid servicing.

The use of one type of valve right throughout the amplifier has much to be recommended. The low operating volts (60 V.) are to be noted, this leads to the use of small batteries. The whole problem of the life of the batteries has been considered by the Germans and they must have concluded that low voltages lead to the most efficient system. The lamp is heated by a nickel iron battery which has again been adopted in order to reduce weight. The filaments of the valves are however heated from a lead accumulator. These two accumulators are the weak point in the apparatus since they require recharging. The Italian photophone on the other hand is designed to run off dry batteries. The voltages of the batteries are monitored with a single voltmeter the correct setting for each being indicated by a coloured mark on the voltmeter scale.

VIII. RANGE.

The range quoted in the German handbook is 3 Km. for white light and 2 Km. for red light or infra-red radiation. However it is reported that ranges up to 5 miles were obtained in the Middle East.

IX. OPTICAL EFFICIENCY.

Taking the 5 miles range as corresponding to the conditions of zero atmospheric absorption we can calculate the lumens falling on the photocell in the quiescent state of the transmitter. We will take this as a measure of the sensitivity to a speech modulated beam. Using the above assumptions and remembering that the receiver lens has an area of π 16 sq.cms. the lumens falling on the photocell will be

$$\frac{10,000}{(9000)^2} \times \frac{50}{(400)^2} = \frac{50}{8\pi} \times 10^{-6} = 6.2 \times 10^{-7}$$

We may compare this figure with the results obtained for a B/T cell with light modulated at 500 cycles. For white light the corresponding lumen sensitivity will be 6.2×10^{-8}. For speech this figure will have to be much larger. From this fact we can assume that the lumen sensitivity of the German photocell is of the same order as that of the British B/T cell, a fact which has already been reported from laboratory measurements (see XI).

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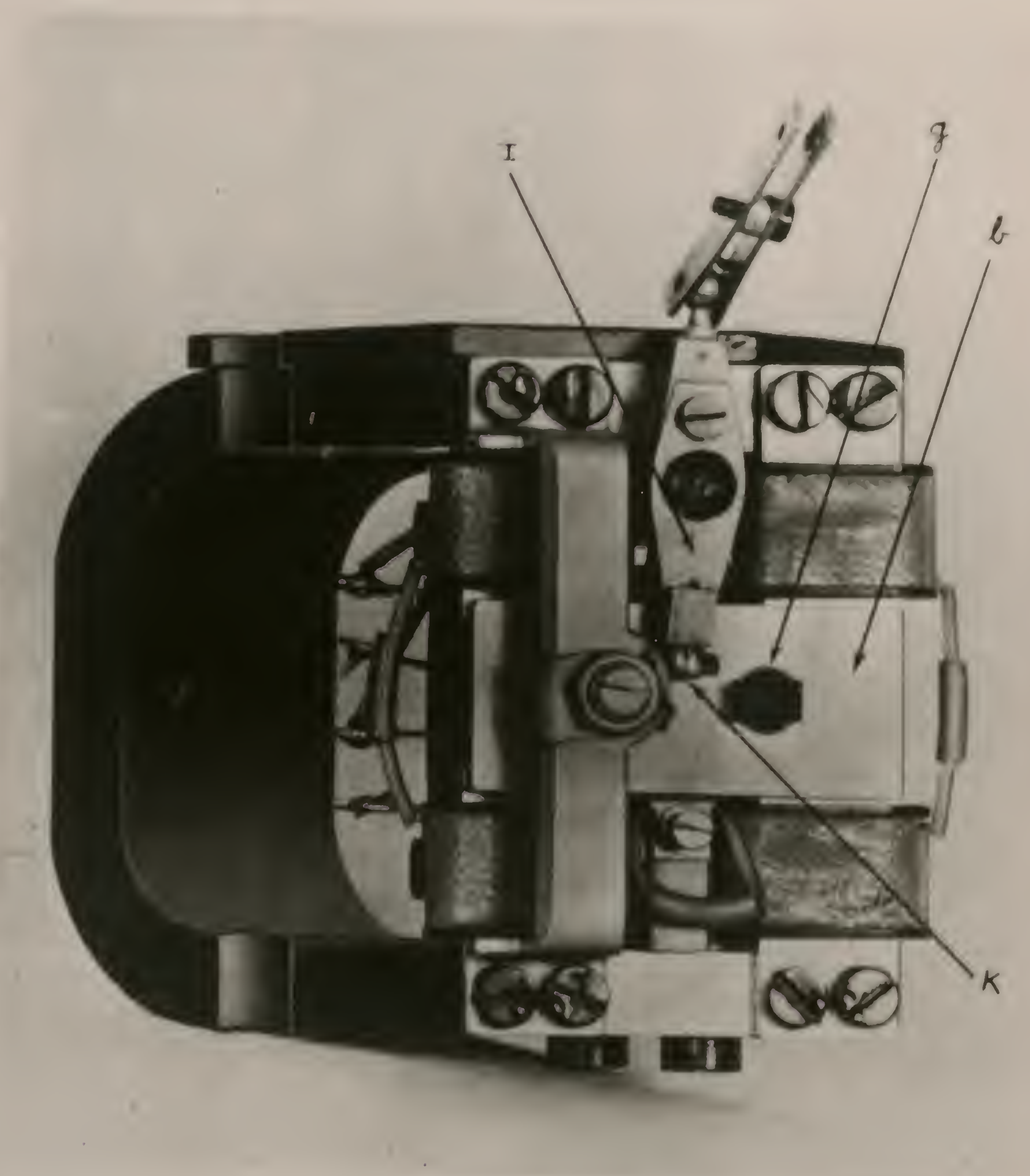

Fig. 1.

View of the modulator.

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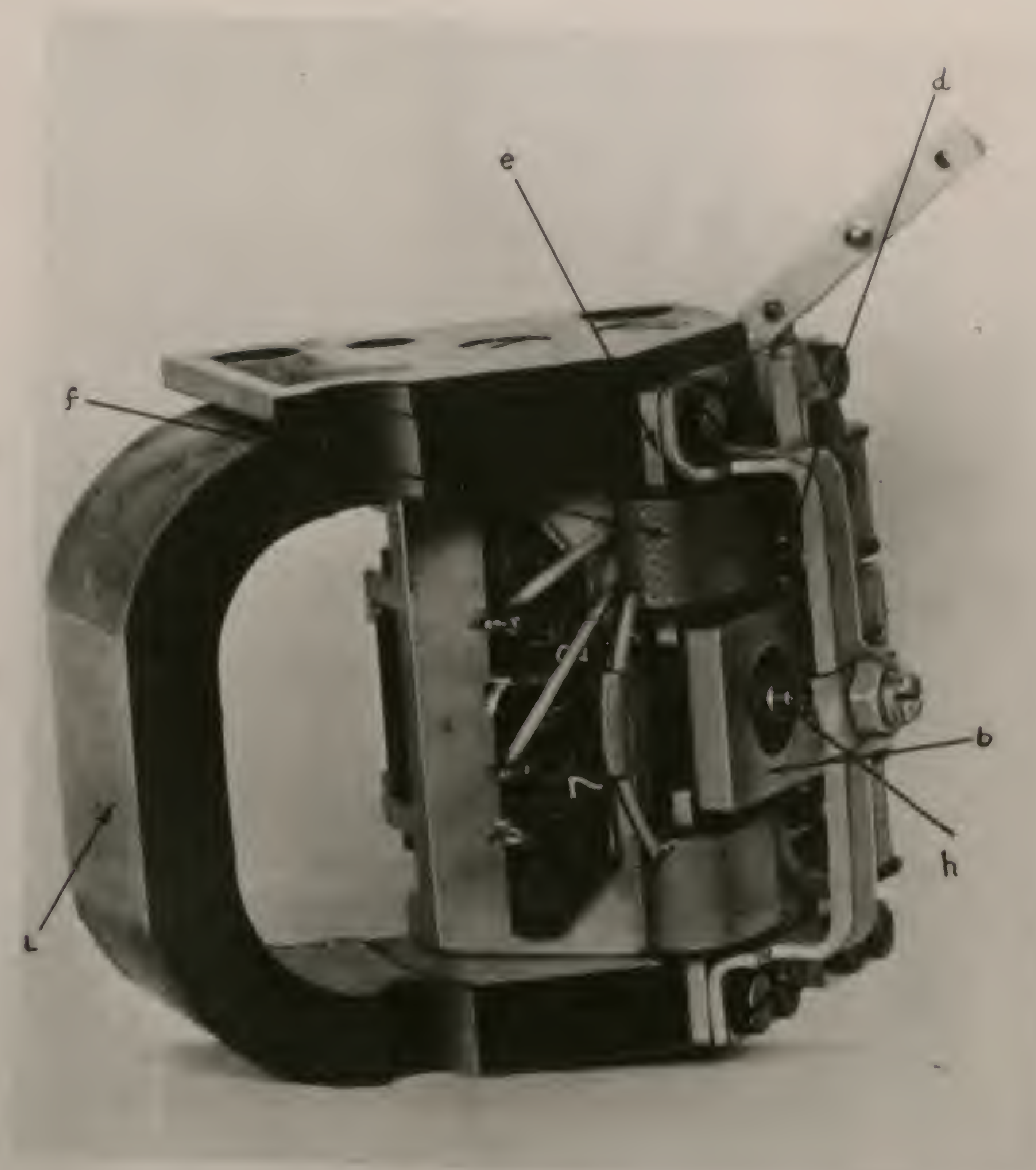

Fig.2.

View of the modulator.

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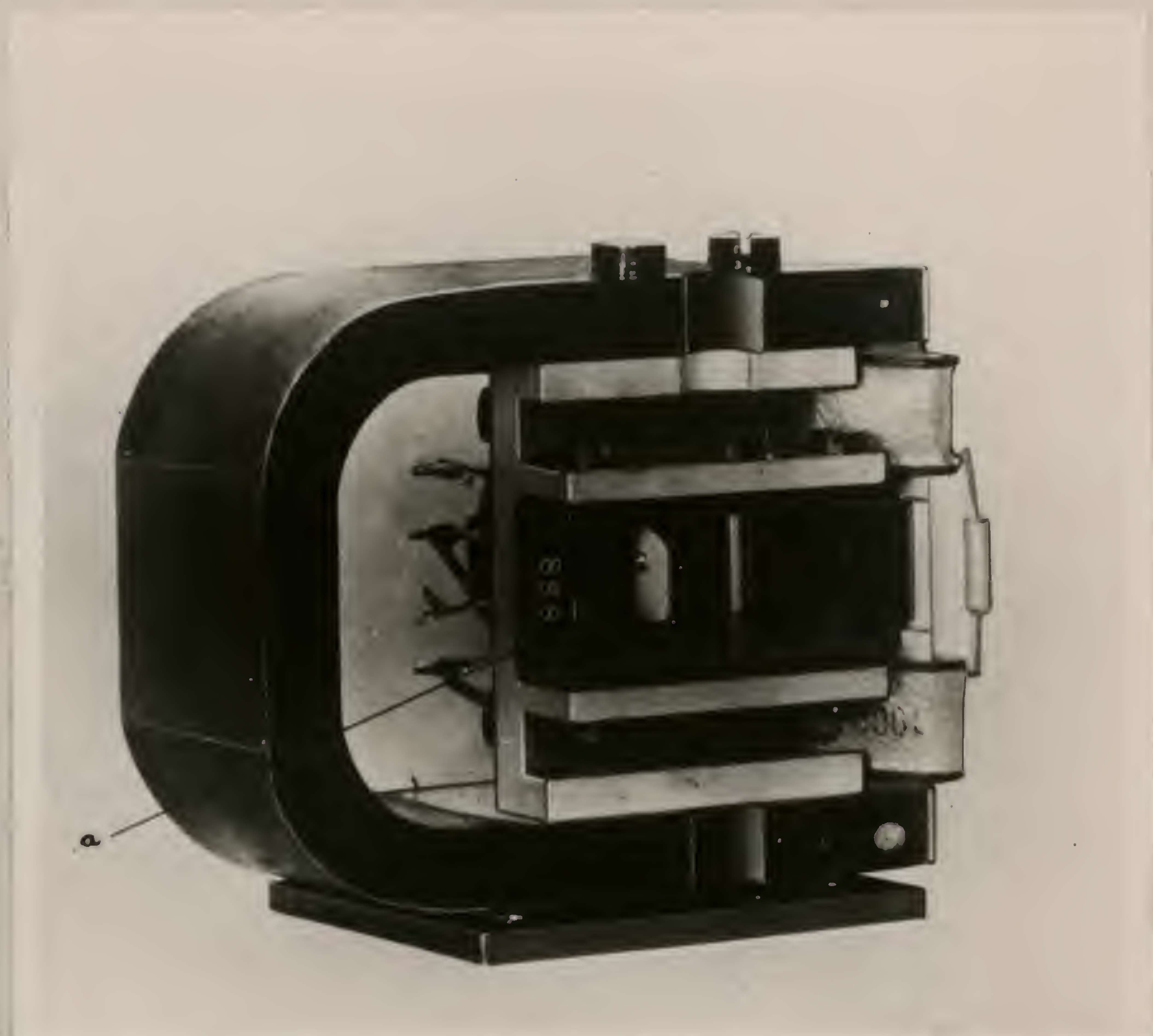

Fig. 3.

View of the Modulator.

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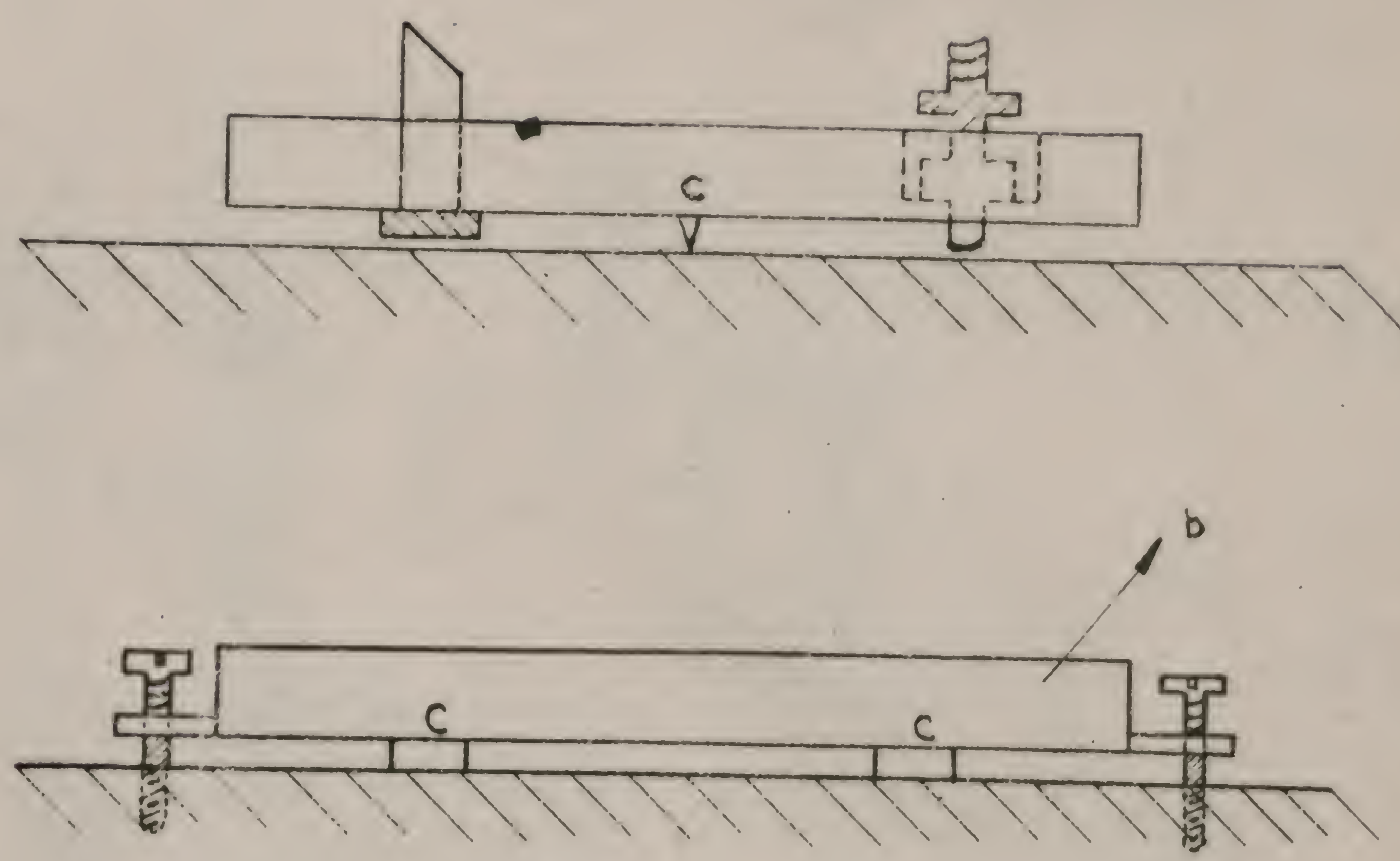

FIG 5.

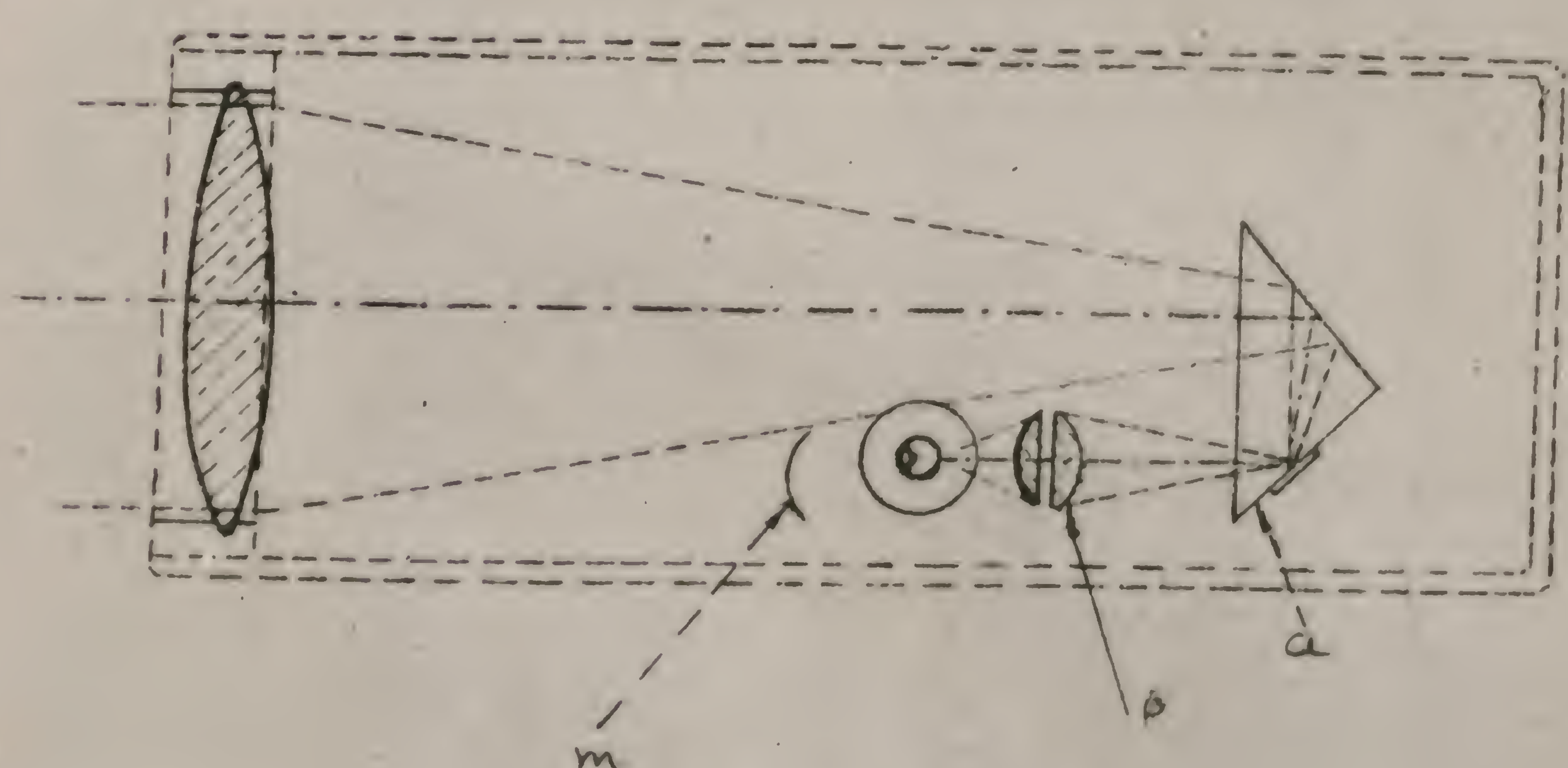

FIG 4.

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Fig. 6.

General view of the transmitter head.

A.S.E. 10849.

Fig. 7.

Tripelstreifen.

A.S.E. 10852.

Fig. 12.

Photocell.

A.S.E. 10853.

Fig. 13.

Back view of photocell.
(Note press studs).

Fig. 8.

Front view of transmitter-receiver head.

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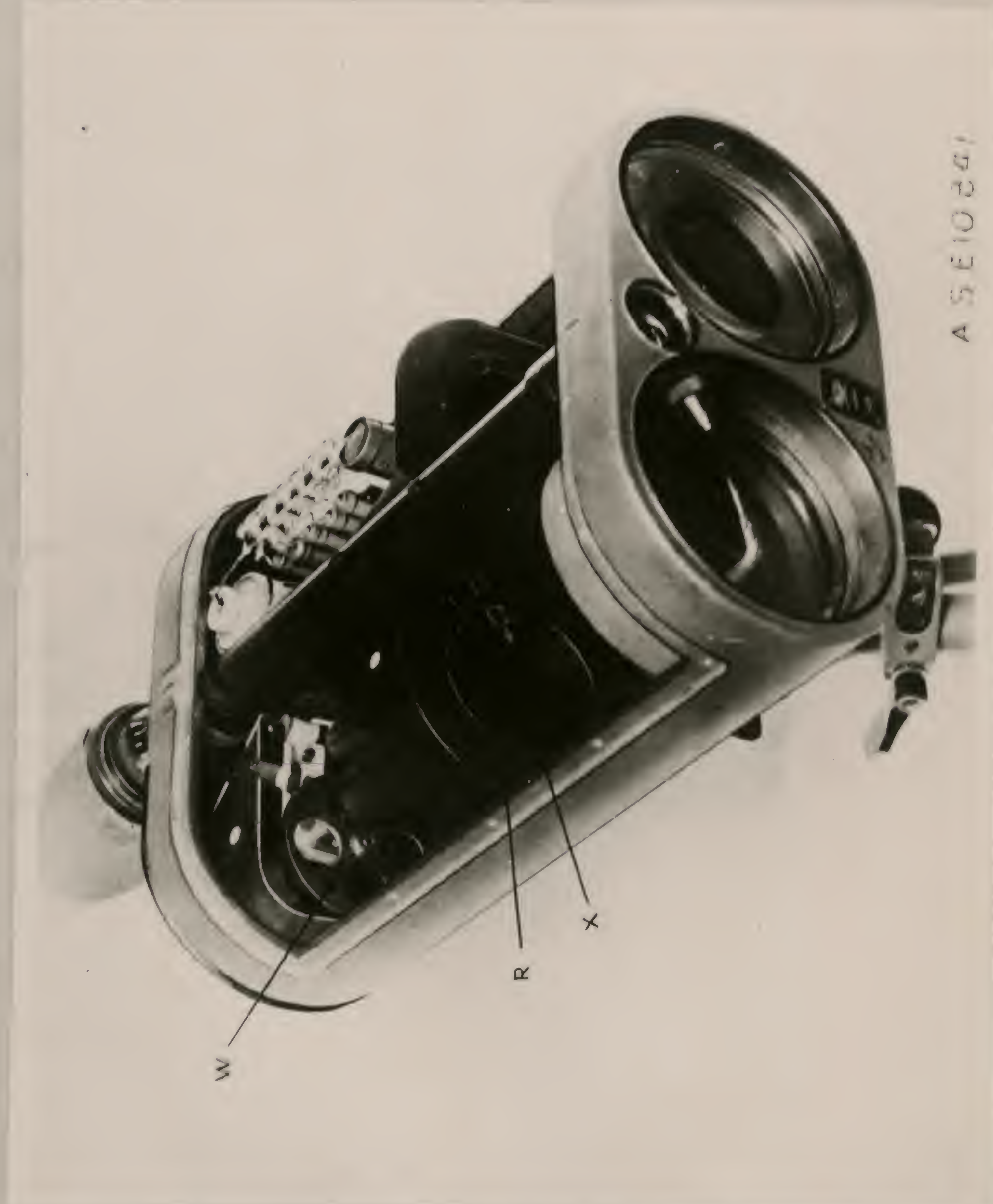

Fig. 9.

View of interior of head.

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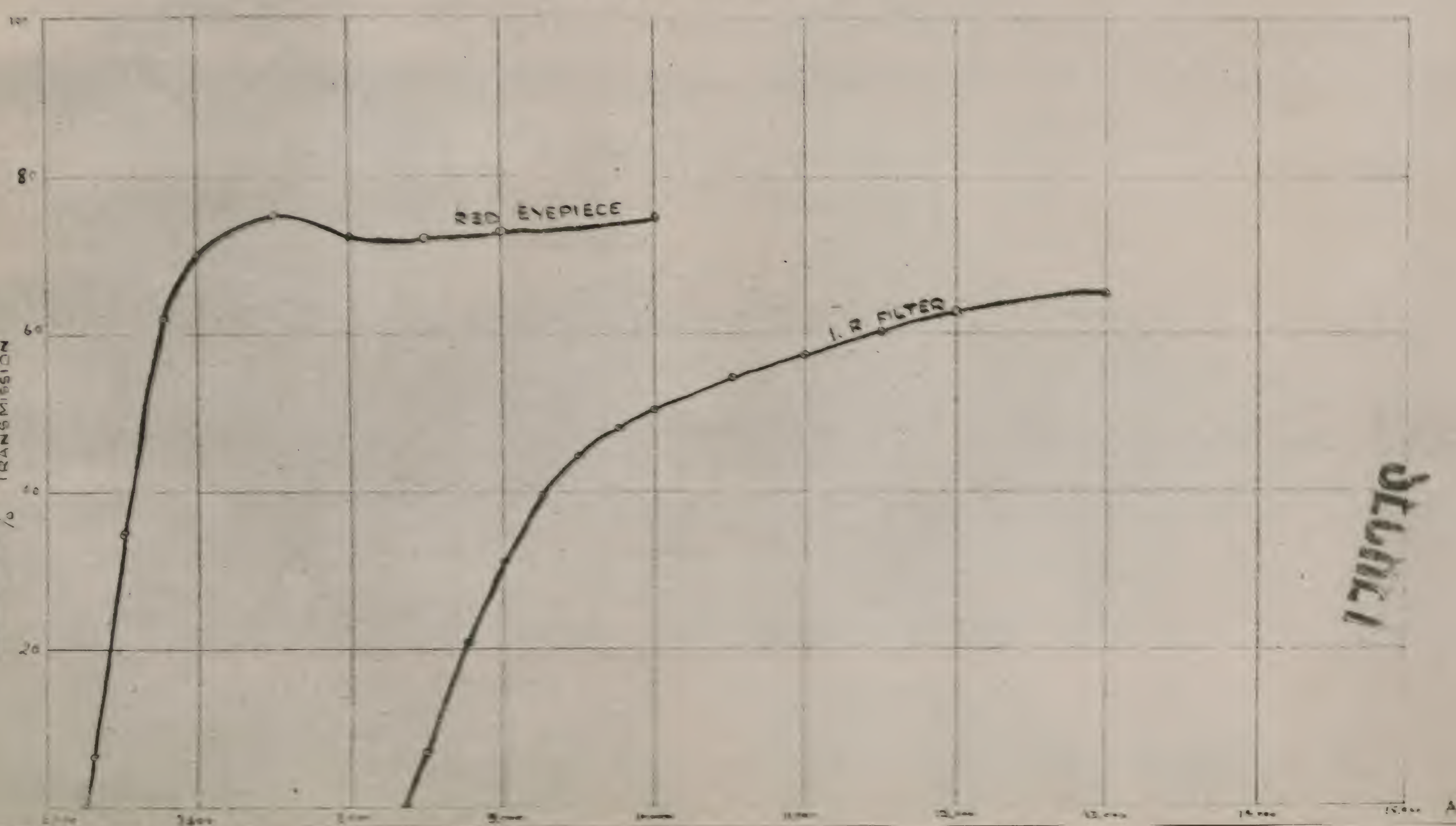
FIG 10

SPECTRAL TRANSMISSION CURVES



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SECRET

Fig. 11.

Wheel carrying filters
On left German Valve RV2P800.

SECRET

SECRET

Fig. 14.

Shadow graph of the filament of the lamp.

SECRET

SECRET

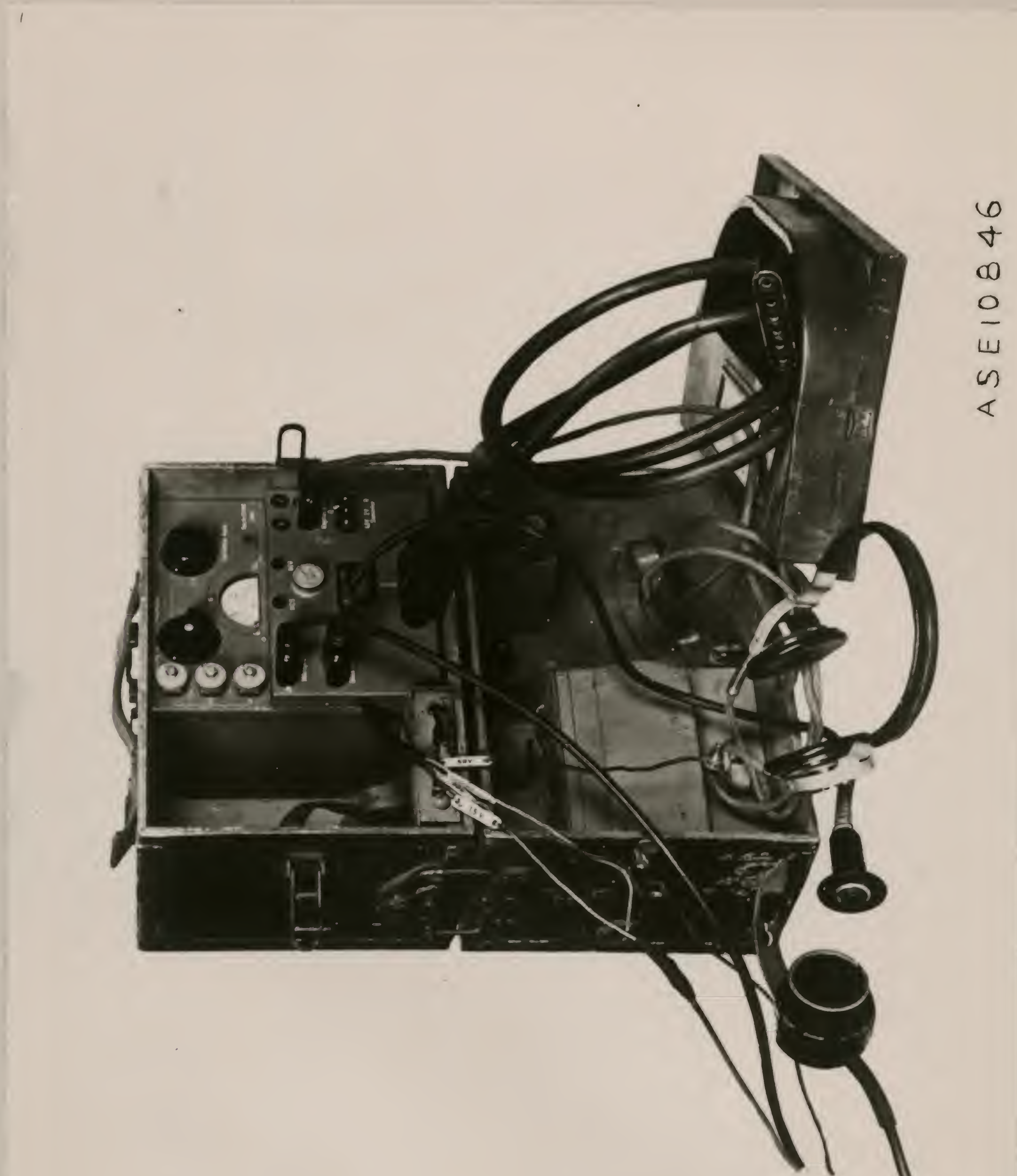

Fig. 15.

General view of the amplifier boxes.

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CIRCUIT DIAGRAM

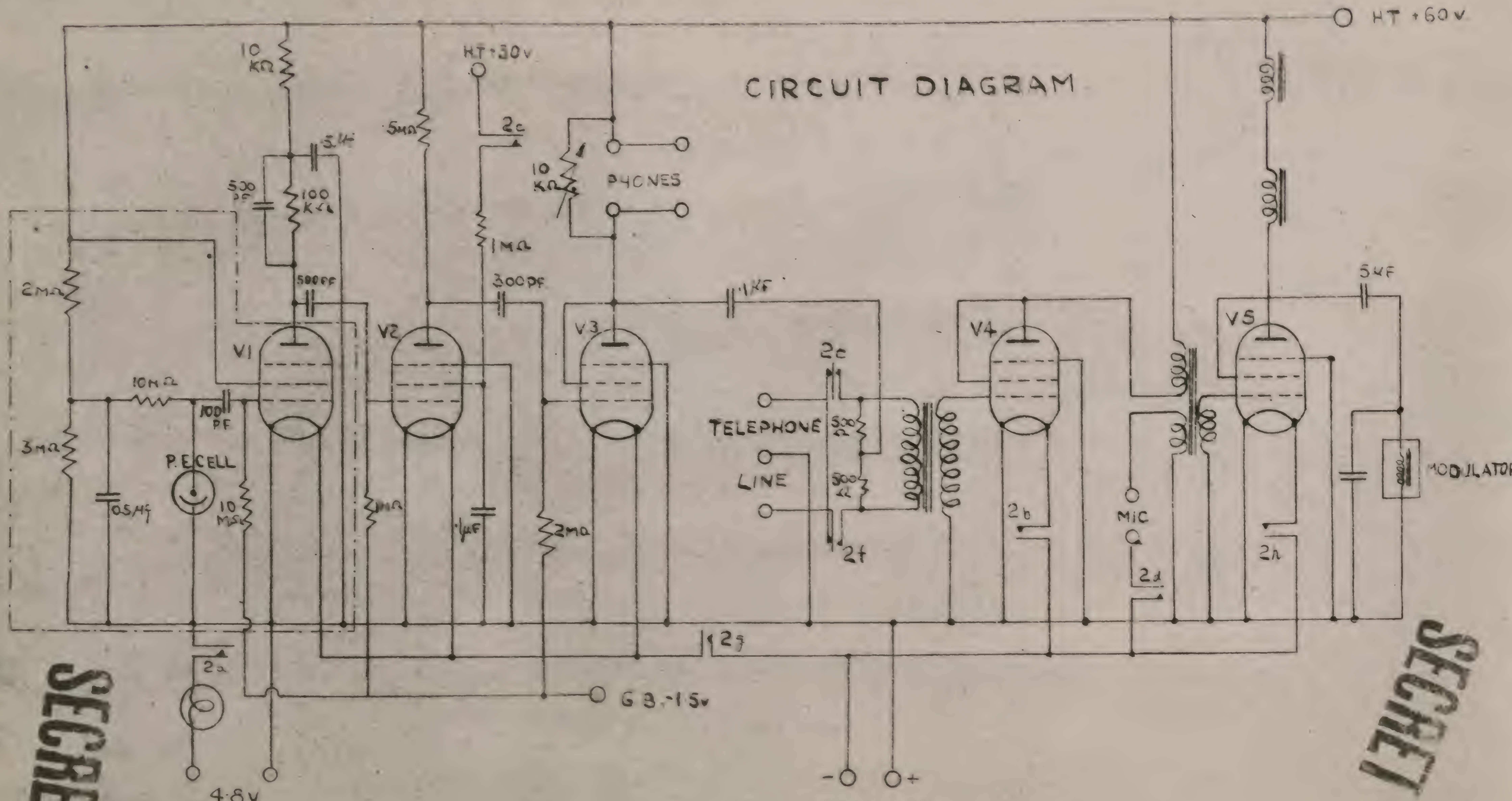

FIG 16

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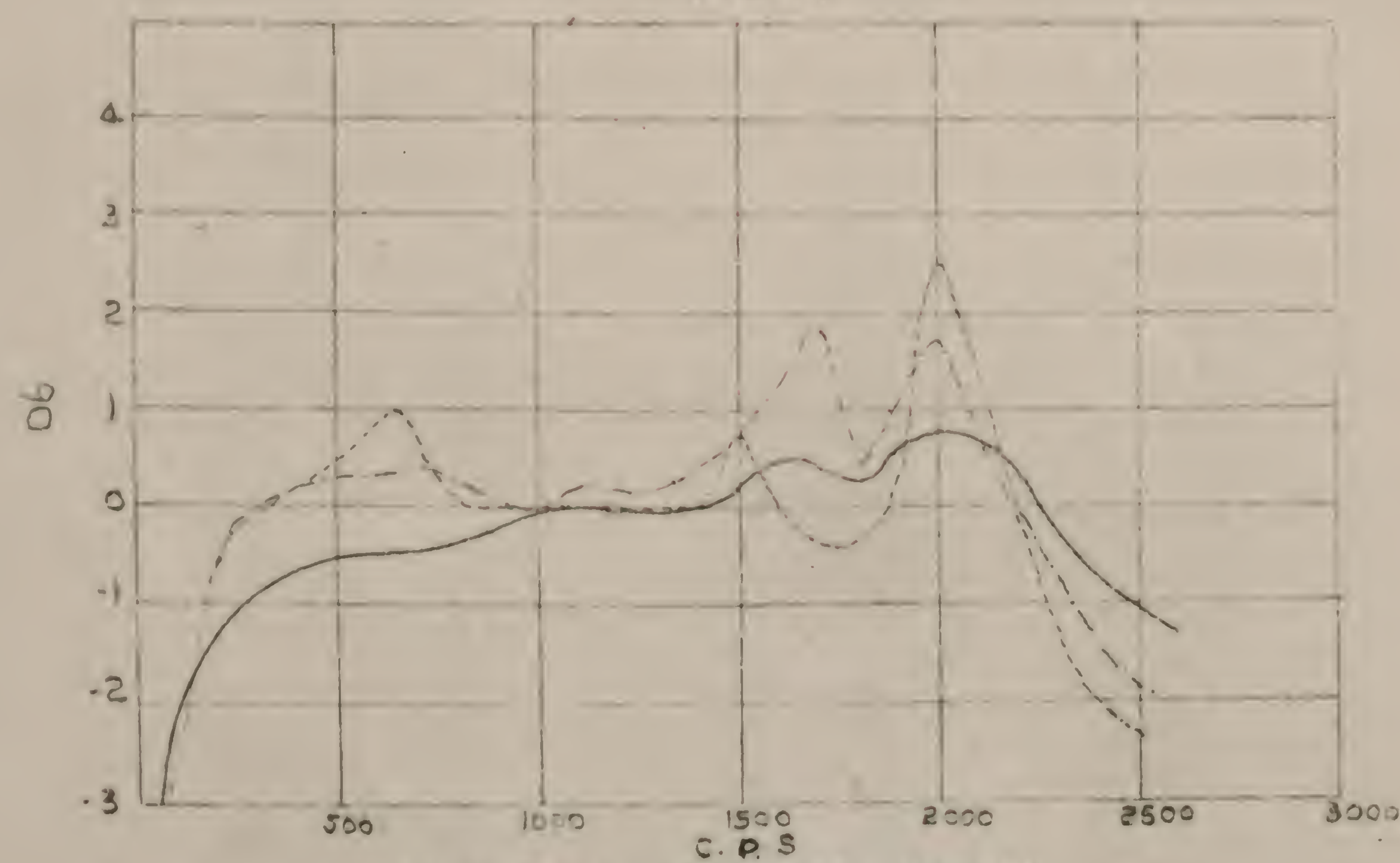
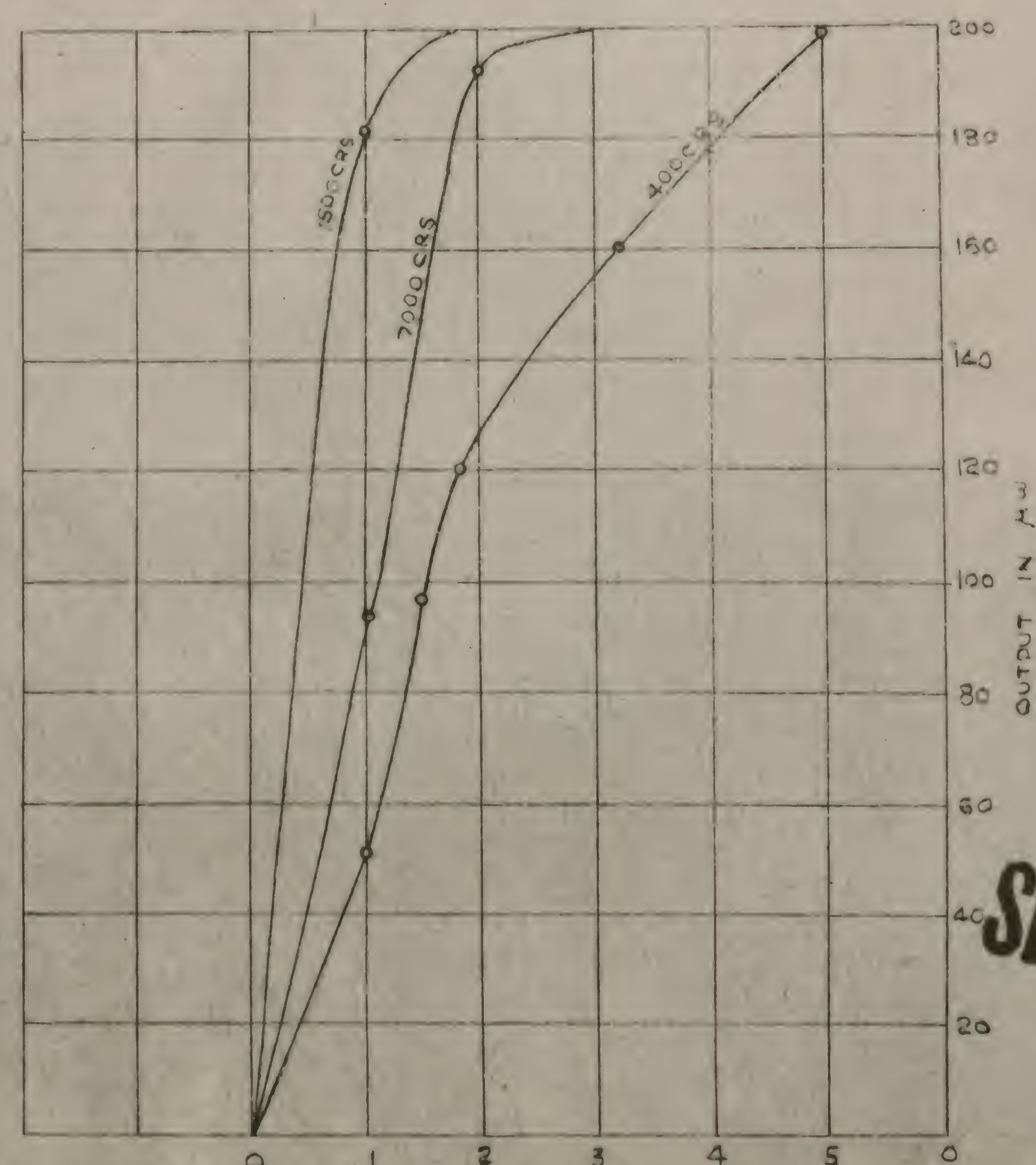
FIG 17



FREQUENCY RESPONSE CURVES

...... 60 db BELOW 5V INPUT
-·-·- 48 db " " "
——— 20 db " " "



INPUT VOLTS

DEPTH OF MODU[illegible]

FIG 18

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